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Stranded oil of Erewhon☆

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ABSTRACT

Recently, there has been an expression of concern that vast quantities of oil must remain in the ground because of anticipated action on climate change. A consequent fall in share values of international oil companies may threaten pensions, small investments and even the stability of the financial system. The threat is held to warrant policy intervention to provide more information to small investors. Consideration of the technology of oil extraction and of the options available to oil companies suggests that there is little basis for the concern.

1. Introduction: the problem of stranded oil

In recent years, some commentators have observed that a successful, global policy on climatic change in which a tax is imposed on emissions of greenhouse gases may lead to a dramatic reduction in the share prices of the major independent oil companies (IOCs, e.g. Exxon, BP and Shell). Since these companies loom large in some countries' stock markets, it is reasoned that a threat to the levels of these markets themselves may ensue, with strong effects on the general economy and on the pensions and other financial holdings of small savers.

For example, Mark Carney, the Governor of the Bank of England, has warned that "investors face 'potentially huge' losses from climate change action that could make vast reserves of oil, coal and gas 'literally unburnable'…Once climate change becomes a defining issue for financial stability, it may already be too late." (Clark, 2015). Carney's remarks are based on findings by, among others, Carbon Tracker Initiative (2013) and the Bank of England's Environmental Audit Committee (2014) that stock markets are over-valuing companies that produce and use carbon. They urge investors to take climatic risk into account in their investments. The reason is that implementation of a policy of limiting global warming to two Celsius degrees above pre-industrial levels (a common benchmark in discussions of climate) necessitates a *carbon budget* for the world in which only a small fraction of proven reserves can be used. If the value of all its reserves is discounted into a company's share price, that price can be expected to tumble once the redundancy of reserves becomes widely apparent.

Baron and Fischer (2015) argue for greater transparency of information about the potential for climate action to affect share prices. Caldecott (2010) has interpreted earlier Carbon Tracker findings as implying that institutions and individuals are investing in carbon-intensive assets without understanding the risk involved. Many shareholder groups are insisting that independent oil companies (IOCs) provide such information in their annual reporting to shareholders, including New York City and the State of California.

Proponents of this view declare that estimates of the expected discounted net cash flows from extracting these reserves are the fundamental data on which an IOC's share price is determined. If, as a result of an international agreement, a carbon tax is imposed approximating current estimates of the *social cost of carbon*,[2] many assets that are now profitable will become unprofitable. The companies' net cash flows will be substantially reduced and in turn the share price will decrease sharply.

Indeed, making some oil properties unprofitable is the purpose of this *Pigovian tax*[3] (or of regulation to limit cumulative emissions cumulatively or to limit temperature change). The intent is that properties that cannot cover the costs of damages imposed on society from emissions as well as their costs of production will not be exploited and their oil will remain in the ground.

Academic discussion relies on a Hotelling (1931) analysis of oil extraction with a *stock effect*: As the stock of oil is extracted, recourse is

☆ *Erewhon* is a satirical, nineteenth-century novel by Samuel Butler. It takes place in the topsy-turvy land of Erewhon ("Nowhere" spelt, nearly exactly, backwards)

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[2] The social cost of carbon is the present value of costs imposed by the marginal ton of carbon dioxide emitted.

[3] A Pigovian tax (after the economist A.C. Pigou) aims to internalize decisions about harmful actions by charging (an estimate of) the marginal damages as a tax. If a constraint is imposed, such as a limit to a two-degree increase in ambient temperature, it is the sum of the discounted marginal future values of lifting the constraint (cf Cairns, 2004). In this paper, the word "tax" is used, but the ideas apply to regulation and to subsidization of renewable fuels as well.

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made to reserves of ever lower quality. The industry dwindles as the marginal cost of production rises toward the intercept of the world demand curve. Suppose that the highest price that anyone is willing to pay for a barrel of oil is P. If a tax τ is imposed on each barrel, any oil with marginal cost between P and P-τ becomes unprofitable and must be left in the ground. The analysis provides a theoretic backdrop to the global calculations cited by Carbon Tracker and, in general terms, points to which stocks are not extracted in a cost-minimizing transition to the closing of the industry.

The result is a purely supply-side response; it does not rely on, say, consumers' eschewing the use of oil other than through reacting to its price. For the tax to prevent the high social costs of burning the oil, these reserves must be a large portion of the reserves of the companies. The oil that is projected to be left in the ground is said to be *stranded* by the tax.

A Hotelling analysis with a stock effect is a sectorial analysis of the oil industry. It is based on a set of strong assumptions, including that decisions in the oil industry are essentially taken at the sectorial level. In fact, decisions in the industry are taken at the firm level. The world market does not exhibit a smoothly operating equilibrium through time as depicted, but a clumsy progression of temporary price fixings. Price lurches from one fixing to the next as conditions change from moment to moment and firms react, including by opening and closing oil properties (Smith, 2009). Firms' decisions cannot readily be assembled to estimate an equilibrium price trajectory.[4] A share value is an instantaneous value determined by aggregating the current opinions of potential buyers and sellers.

The present paper considers the rational response of an IOC, such as BP, Exxon, Chevron or Shell, to climatic change and the implications for the path of its share value through time. It is not an advocacy of any particular policy regarding climate, and certainly is not an argument for not internalizing the cost of carbon. Rather, it is an examination of what faces an IOC in the present day as well as investors in the IOC.

2. "Stranded assets"

The very discussion of stranded assets is salutary in the economic analysis of the oil industry: it heralds a recognition that irreversible investments have a vital influence on industry decisions. Stranded assets are *sunk* assets, assets whose costs cannot be fully recovered when their profitability is (much) lower than expected.

Because it abstracts from sunk costs, however, the Hotelling model with a stock effect is ill suited to studying stranded assets. The model is limited to considering as stranded only the high-cost oil that is abandoned in an ordered sequence of use. An argument of the present paper is that it is precisely this oil that is *not* stranded. The reason, developed below, is that there will not be investment in such resources: Nothing will be committed to, or sunk in, them.

A first consideration is to be more precise in use of the term, "stranded". It originates in regulatory economics from the observation that a regulator's actions can potentially have drastic effects on the financial viability of some regulated assets. According to Crew and Kleindorfer (1999), "Assets are considered stranded when they were prudently acquired but have lost economic value as a direct result of an unforeseeable regulatory or legislative change specific to the industry in question."

Ploeg (2016) considers potential risks to the oil industry: "Oil and gas producers face three threats: prolonged low oil and gas prices, tightening of climate policy and a tough budget on cumulative carbon emissions, and technological innovation producing cheap substitutes for oil and gas. These threats…lead to the problem of stranded assets and a significant downward valuation of oil and gas producers." Crew and Kleindorfer's definition admits only the second, a tightening of climate policy and a tough budget on cumulative emissions, as potentially producing stranded assets – at that only if one concedes that climate policy can be held to be unanticipated by investors.

For example, many coal reserves are currently being abandoned, not because of an environmental policy related to climatic change or other problems[5] but because of a sharp fall in the price of substitutes, mainly natural gas but also renewable energy.[6] This fall has been largely because of the so-called shale revolution based on innovations in *fracking* and horizontal drilling. It is not because of a policy but because of the commercial risk that arises from competition and technological change.

On the other hand, after the Fukushima disaster in 2011, some governments rushed to insist that their producers exit the nuclear generating industry. Share values of uranium miners fell and have remained depressed. Toshiba, which took over Westinghouse's production of nuclear reactors, has filed for bankruptcy as a result of the change in policy. The situation is similar to the one after the event at Three Mile Island in 1979. In the aftermath of regulatory change at that time, Westinghouse's share value tumbled. In this case the abandoned assets, including uranium mines and un-utilized reactors, can be considered to be stranded.

The oil industry has seen much adjustment since the significant and continuing drop in prices beginning in 2014. The adjustment has not been the result of regulation directed at climatic change but of the normal operation of the market. World share markets have been stable.

One must be careful with the distinction. One is the result of the action of markets in favoring superior alternatives; it is a normal business risk. The other is the result of action by a regulator, outside the market, that takes actors by surprise after they have made commitments to particular activities. In a market context it is extraordinary.[7]

3. Analytical problems

If one is to make policy one must delve into the technology and the decision making of the firm.

Exploration is central to finding new reserves for eventual extraction. It turns up (a) "dry holes" containing no oil or gas, (b) quantities of oil or gas that cannot be profitably exploited, (c) quantities sufficient that the properties will eventually become profitable under given assumptions, and (d) a few reserves that are currently profitable. For an IOC to remain a going concern, new reserves have to be found regularly or else bought from firms that are specialized in exploration or other firms. A typical firm has reserves in inventory and plans for developing those reserves for extraction according to future economic conditions.

Even so, exploration carried out at any particular time is not crucial to the future of the firm. While a flow of exploration successes is essential to the continuance of the industry, exploration is highly sensitive to the current price of oil (Boyce and Nøstbakken, 2011; Smith, 2014). Following the downturn in price since 2014, for example, exploration for oil declined precipitously. Furthermore, it is not practicable to assign exploration expenditures to the reserves discovered.

[4] The mathematical reasons are (1) non-convexities that are largely related to irreversible investments, which are overlooked in Hotelling models, as well as (2) the stochastic nature of influences on the industry which make confidence intervals of predictions of temporary equilibria wide and increasing through time.

[5] Coal is a prime candidate for such policy because it emits more carbon dioxide than oil per unit of energy produced and also emits more of other harmful substances, but coal has not faced such policy.

[6] Houser et al. (2017) attribute the sharp decline of the US coal industry between 2011 and 2016 mainly to substitution from alternative fuels but also to declines in US electricity demand and in demands in world markets originating from China. These are all unremarkable market risks that have arisen from changes in economic conditions. Very little of the decline can be attributed to regulation and almost none to regulation aimed at reducing carbon emissions. US capital markets were not destabilized in the period and have not been since.

[7] The removal of ineffectual enterprises is one of the strengths of capitalism. The elimination of successful, prudently made investments is one of the potential ill effects of regulation.

Exploration provides knowledge and reserves, but the relationship between discoveries and expenditures is stochastic. The expenditure is sunk but it is regarded as speculative. In many cases a firm can expense its exploration expenditures against other revenues for tax purposes.

Reserves cannot be extracted until they are developed. An undeveloped reserve should not be viewed as subject to being stranded because no investment has been made in it.

Development investment is comparable to the value of the reserve and is sunk: the reserve and the investment in development are tied together irreversibly. The resulting producing property is what would be considered to be stranded if suddenly the production of oil stopped because of a regulation or tax. The stranded investment is, strictly speaking, the *development investment*.

Development occurs only if the firm expects its investment to be paid back. The firm looks forward to any anticipated events that may affect repayment and assesses the risks. Its eyes are open to the potential for such events as changes in taxes. For example, Exxon has been simulating scenarios for a carbon tax of up to $80 per ton for over a decade (Ward, 2016).

Obviously, there is less information about events in the far future than the near future. In the case of oil, because of the *natural decline* in pressure as oil and gas are extracted according to what is known as Darcy's law, the output of a typical reserve decreases through time; a common assumption is by ten percent per year (Adelman, 1990). Fracking wells decline at an even faster rate.[8] The bulk of net cash flows are produced early and consequently are not heavily discounted. Without eliminating risk entirely, caution exercised in making a commitment and the early extraction of much of the reserve attenuate the risk of stranding the development investment at any particular property. Later in the life of the reserve, production can be *enhanced* (recovery can be increased) by a further investment (Smith, 2014). The decision of whether to proceed with enhancement, at what level, at what time is typically made more than a decade later, after a further assessment of information then available about taxes and other conditions. Conditions of production in the oil industry – the natural decline of output, which is a function of the nature of sunk investment in extraction and of the geological characteristics of the reserve – make any development investment that is actually made much less susceptible to stranding than other types of investment.[9] High-cost reserves that are not developed cannot be stranded.

Because of natural decline, to maintain market share and to maintain its cash flows the firm continually develops new reserves and enhances producing ones. Development investments are made as information is revealed. If conditions are adverse, less development occurs and production declines. Indeed, if it so chose, a firm could stop exploring, curtail development and let its production decline, while still maintaining a good cash flow.[10] Exxon, for one, has let its production slide since 2014. Researchers and journalists are not privy to Exxon's decisions. It is unsurprising that the company might hold back some development expenditure in order to time the use of its reserves for when prices rise as a result of an anticipated economic recovery.[11]

The oil sands of Alberta, Canada are produced through something more akin to open-pit mining than to conventional oil production. The decline rate is negligible for such production. Facilities in the oil sands are large, have high costs and are developed for a few decades. They may be more easily stranded than conventional facilities. The major firms are clearly aware of the possibility of a tax on emissions. They are selling their positions to Cenovus and other Canadian firms that are specialized to the oil sands. The firms that do remain are reacting to conditions by significantly reducing their costs (as well as their emissions).[12]

The upshot is that the underlying value of the IOCs is not the expected discounted value of their reserves. Rather, it is the value of a set of options that emanate from the many possible future paths of the price of oil and other economic variables. A firm can respond to the realized path according to conditions as they unfold (cf Dixit and Pindyck, 1994). In the meantime the firm continues to produce oil and to generate cash flows from its sunk investments.

Among the uncertainties facing an IOC is the likelihood of the implementation of a general carbon tax[13] or an independent tax in any particular jurisdiction where it operates. The Paris Agreement of 2015 does not have any more “teeth” than the Kyoto Agreement of a generation earlier. Game-theoretic analyses tend to find that only a handful of countries will be able and willing to make a *stable* agreement to which they will adhere. Of course, the analyses are theoretical and abstract. Their assumptions may not stand up. For example, some large emitters may be motivated by other values than their own interests and decide “to go it alone” or with a few others. Even so, the analyses urge a tempering of the even more questionable assumption that a new tax or regulatory policy will be sure, sudden, swift and strong.

If an IOC is confident that it can earn high returns in the oil industry, it can invest to explore for more oil and to develop more oil-producing properties at the appropriate time. It can strive to reduce costs. If it is not confident in the future of oil, however, it has other options. It can return much of the cash flow to shareholders as dividends or buybacks (cf Spedding et al., 2013). If it is confident in its expertise in energy it can invest in renewable energy, including through take-overs.[14] Finally, it can use retained cash flows to re-invent itself as a firm in another industry.

Some undeveloped reserves are *in the money* (would be developed

[8] Dale (2015:8–10) points out that shale production, while not a large fraction of world output, has substantially increased the short-term elasticity of total current production to the oil price: exploration and development are much faster than for other sources and the far steeper decline rate means that the investment is recovered in (and hence sunk for) a much shorter period of time. Other sources, which still must incur high sunk costs, must contend with the effects of shale production on elasticity of supply.

A firm's main decisions concern the timing and level of investment based on projections of prices, interest rates and other variables over the life of the investment (Cairns and Davis, 2007). Decisions based on flows, in Hotelling's tradition, are superseded by decisions based on capitalized values of flows. The other sources are more reluctant to invest in what may be a short-term opportunity. For example, Cairns and Calfucura (2012) argue that, facing high uncertainty, Saudi Arabia demurred from expanding in the early 2000s, when in hindsight expansion would have been advantageous. In this options context, marginal production is from shale, even though projected accounting costs per barrel may be lower than those of other potential entrants.

[9] Some assets that use or transport hydrocarbons last for a long time, e.g. power plants or pipelines. If imprudent investments are made in them, some assets may be stranded. The potential for stranding these assets is thus *qualitatively* similar to other assets, including developed oil reserves. Oil and gas reserves (apart from oil sands) are *quantitatively* different, however, because of natural decline. They are much less subject to stranding because much of their physical production is concentrated in early years and, moreover, is for that reason not heavily discounted. If the company's discount rate is 0.08 and the decline rate is 0.10, then after seven years only about 30% of net present value remains in the ground, as compared to about one-half of remaining present value for a non-declining production profile. The present paper limits itself to a discussion of oil and gas producers.

[10] Analyst Allen Good argued that oil companies were becoming “cash flow machines” even with the sharp decline of prices since 2014.

[11] Note the following report from the financial press (Koenig, 2018). “Exxon and Chevron are earning billions and benefiting from the new tax law, but profits are falling short of expectations that were based on rising oil prices. The shares of both companies fell in afternoon trading Friday…Exxon's production fell…by 3 per cent from a year earlier, to about 4 million barrels of oil a day. ‘This company just cannot get production growth going,’ said Brian Youngberg, an analyst with Edward Jones. ‘They talk about all these (new) projects, but they're always in the future. People want to start seeing some results’”.

[12] Suncor's extraction cost in the oil sands has dropped by more than ⅓ between 2013 and 2017 (Anwar, 2018).

[13] One fervently hopes that a worldwide climate policy will be implemented. The present discussion, however, is a positive discussion of the response of an IOC to current conditions and of the likelihood of stranding assets.

[14] “Only about 5 per cent of Total's assets are in low-carbon technology so far but Patrick Pouyanne, chief executive, expected this to grow in the long term. ‘We want to remain an oil and gas company but … we have a social responsibility to prepare for the future,’ he said” (Ward, 2016).

now) and some are not. The value of the option to develop each of them is positive, and an option that is out of the money is more highly leveraged to the oil price than one that is in the money. Participants in options markets for IOC shares are likely to be aware of proposals to address climate change and their chances of being adopted. The advice of Spedding et al. (2013), to invest in firms with low costs, then, may be prudent for small, more risk-averse investors, but should be tempered as well.

4. Conclusion

There will be a transition to a carbon-free world, with much oil left in the ground, through a combination of technological change and of policy that encourages a movement "off oil". One conjectures that the industry will face serious challenges, including continuing downward pressure on prices from both the relatively swift reaction of shale producers to opportunities and the continuing development of alternative sources of energy.

However, this conjecture does not imply that oil assets with significant value will be stranded. Both exploration and development in the industry are highly sensitive to the current price of oil and to anticipations about future prices: Investments are made only if there is good reason to expect that they will be profitable. Brief consideration of the technology of production indicates that the assets sunk in the oil industry have only limited susceptibility to stranding because of a feature particular to the industry, namely, natural decline of production from a well. By the time a climate policy is introduced much of the value from developed reserves will have been paid back. Moreover, those reserves will remain competitive against new developments, which must be expected to pay back their newly incurred sunk costs.

The transition may well be orderly. Comparable challenges in 2008 and 2014 have not given rise to stranded assets. Industry responses to policy are being studied and are influencing decisions. Producers are now limiting attention to the most profitable opportunities for investment. Less profitable ones may never be developed.

The questions for investors relate to all of the options, not to the necessity of developing known oil properties or continuing to explore, unless those are the best options at the time of a decision. Will a company return value to shareholders? If the suspicion is no, the investor should consider selling the shares. If it is yes, the investor should consider keeping the shares. Investors currently seem to be cautious about North American pipeline companies. To the extent that the companies are vulnerable to stranding, some of that vulnerability may already be being discounted into the price of shares. There is no reason to suppose that the market is not adequately pricing the risk of climatic action.

It may well be unhelpful to small investors if a company publishes only a few predictions about what options may be available to respond to a carbon tax that is expected to be introduced at an unknown date and with an unknown stringency. One should be especially wary of assuming that disinterested actors are more proficient at an evaluation of future conditions than actors who have a direct interest in it. Aggregating a diversity of interpretations into a current but continually adjusting value is the forte of the share and options markets. In the current decade, oil companies' shares have fallen in value without a dire effect on capital markets or pensions.

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